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H04B 10/18

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H4B BK18

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GB 2303984 A GB 2299473 A GB 2268018 A
EP 0730354 A US 5636046 A US 5224183 A

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INT CL[6] H04B 10/18
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(54) Abstract Title
WDM optical signal dispersion compensation

(57) The WDM optical signal transmission apparatus comprises a main optical fibre 1 and two dispersion compensators 13 and 14, 24 and 23, one at each end of the main optical fibre 1. All the WDM channels are allocated to the normal dispersion region of the main optical fibre 1. The dispersion compensators are composed of second dispersion compensators 14, 24 for compensating the negative dispersion of the centre channel accumulated in the main optical fibre 1 and first dispersion compensators 13, 23 for compensating the additional dispersions of the other WDM channels. Since the second dispersion compensators 14, 24 can be used as parts of the transmission line 1, the dispersion compensators as a whole can be small-sized when compared with those in conventional systems. The first dispersion compensators 13, 23 comprise a plurality of separate dispersion compensating fibres, one per channel, connected to (de)multiplexers.

FIG.1

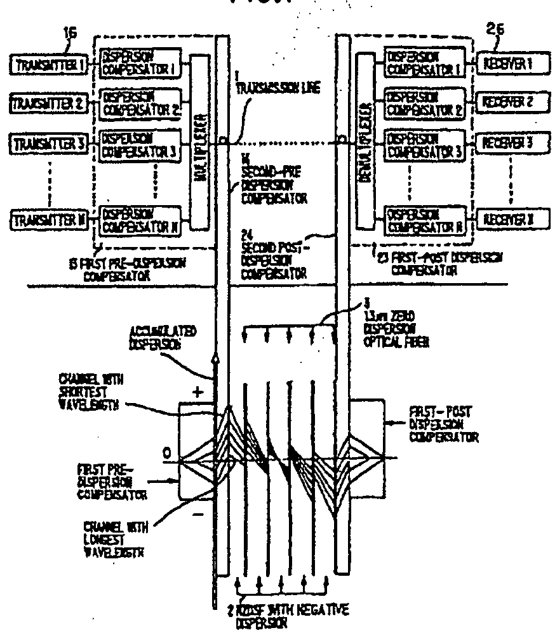

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FIG.1

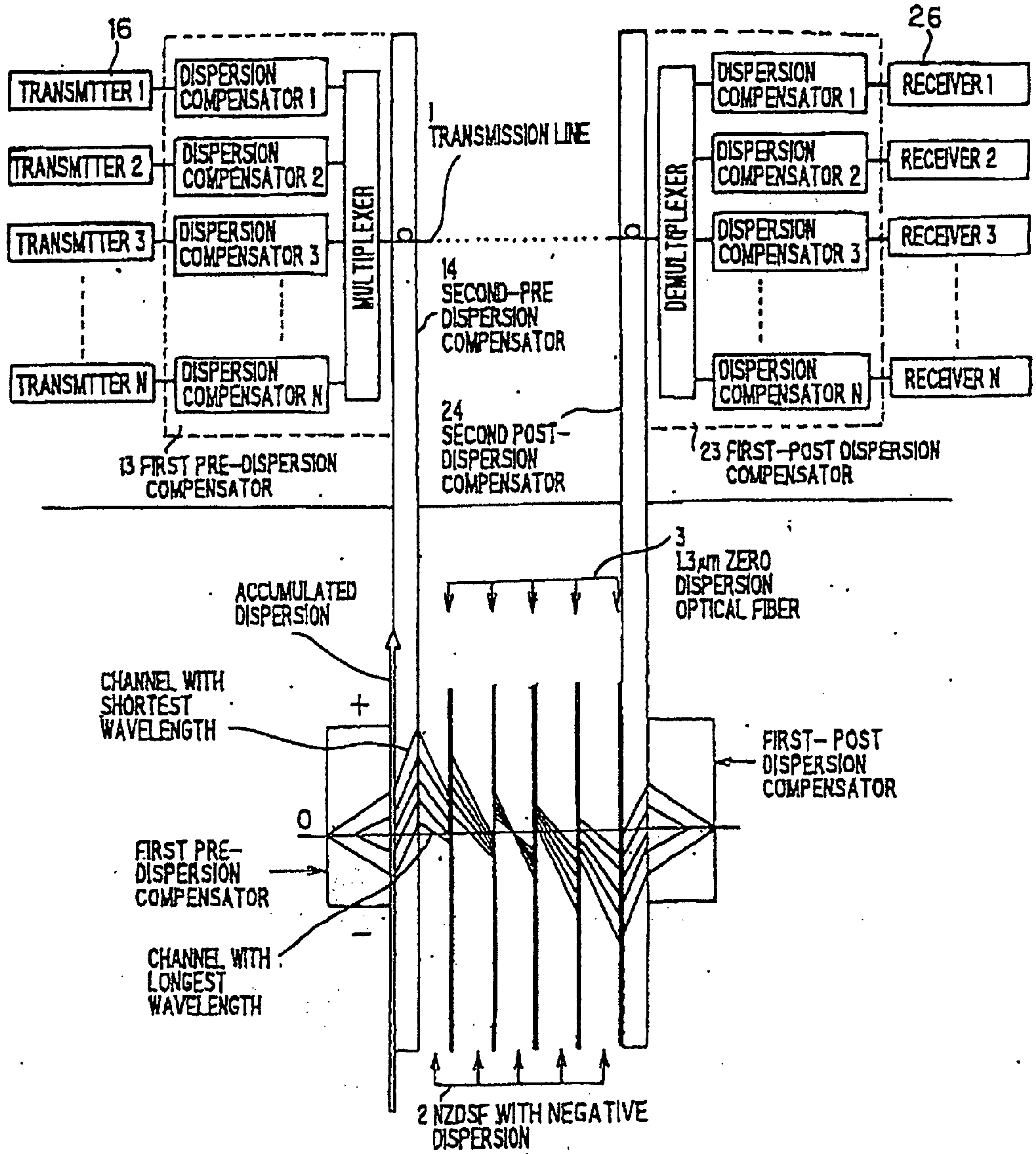
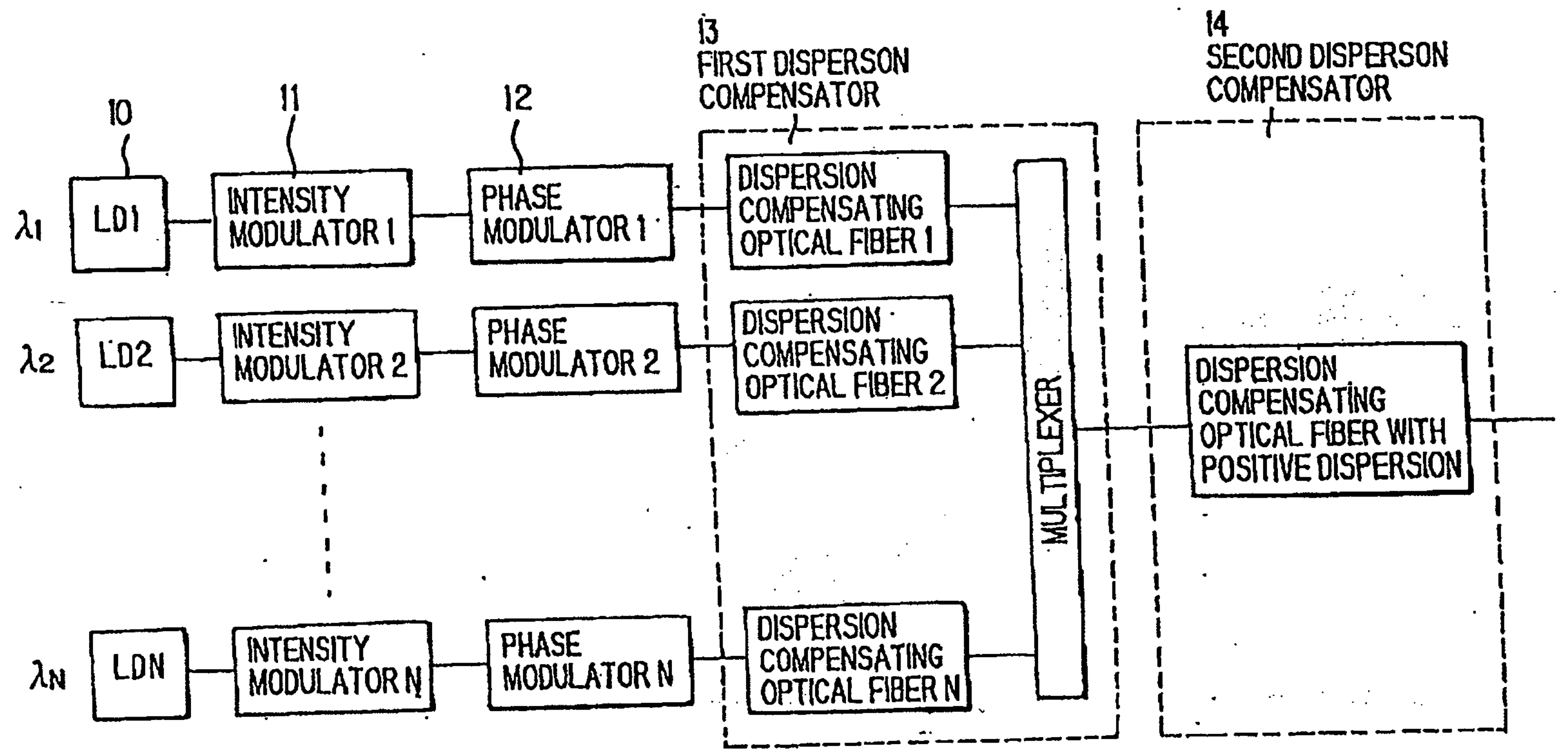

16
TRANSMITTER 1
TRANSMITTER 2
TRANSMITTER 3
TRANSMITTER N
DISPERSION COMPENSATOR 1
DISPERSION COMPENSATOR 2
DISPERSION COMPENSATOR 3
DISPERSION COMPENSATOR N
MULTIPLEXER
1 TRANSMISSION LINE
14 SECOND-PRE DISPERSION COMPENSATOR
24 SECOND POST-DISPERSION COMPENSATOR
13 FIRST PRE-DISPERSION COMPENSATOR
DEMULTIPLEXER
26
RECEIVER 1
RECEIVER 2
RECEIVER 3
RECEIVER N
23 FIRST-POST DISPERSION COMPENSATOR
3 1.3µm ZERO DISPERSION OPTICAL FIBER
ACCUMULATED DISPERSION
CHANNEL WITH SHORTEST WAVELENGTH
+
0
-
FIRST PRE-DISPERSION COMPENSATOR
CHANNEL WITH LONGEST WAVELENGTH
FIRST-POST DISPERSION COMPENSATOR
2 NZDSF WITH NEGATIVE DISPERSION

FIG.2A



10
11
12
13
FIRST DISPERSON COMPENSATOR
14
SECOND DISPERSON COMPENSATOR
λ_1
LD1
INTENSITY MODULATOR 1
PHASE MODULATOR 1
DISPERSION COMPENSATING OPTICAL FIBER 1
λ_2
LD2
INTENSITY MODULATOR 2
PHASE MODULATOR 2
DISPERSION COMPENSATING OPTICAL FIBER 2
λ_N
LDN
INTENSITY MODULATOR N
PHASE MODULATOR N
DISPERSION COMPENSATING OPTICAL FIBER N
MULTIPLEXER
DISPERSION COMPENSATING OPTICAL FIBER WITH POSITIVE DISPERSION

FIG.2B

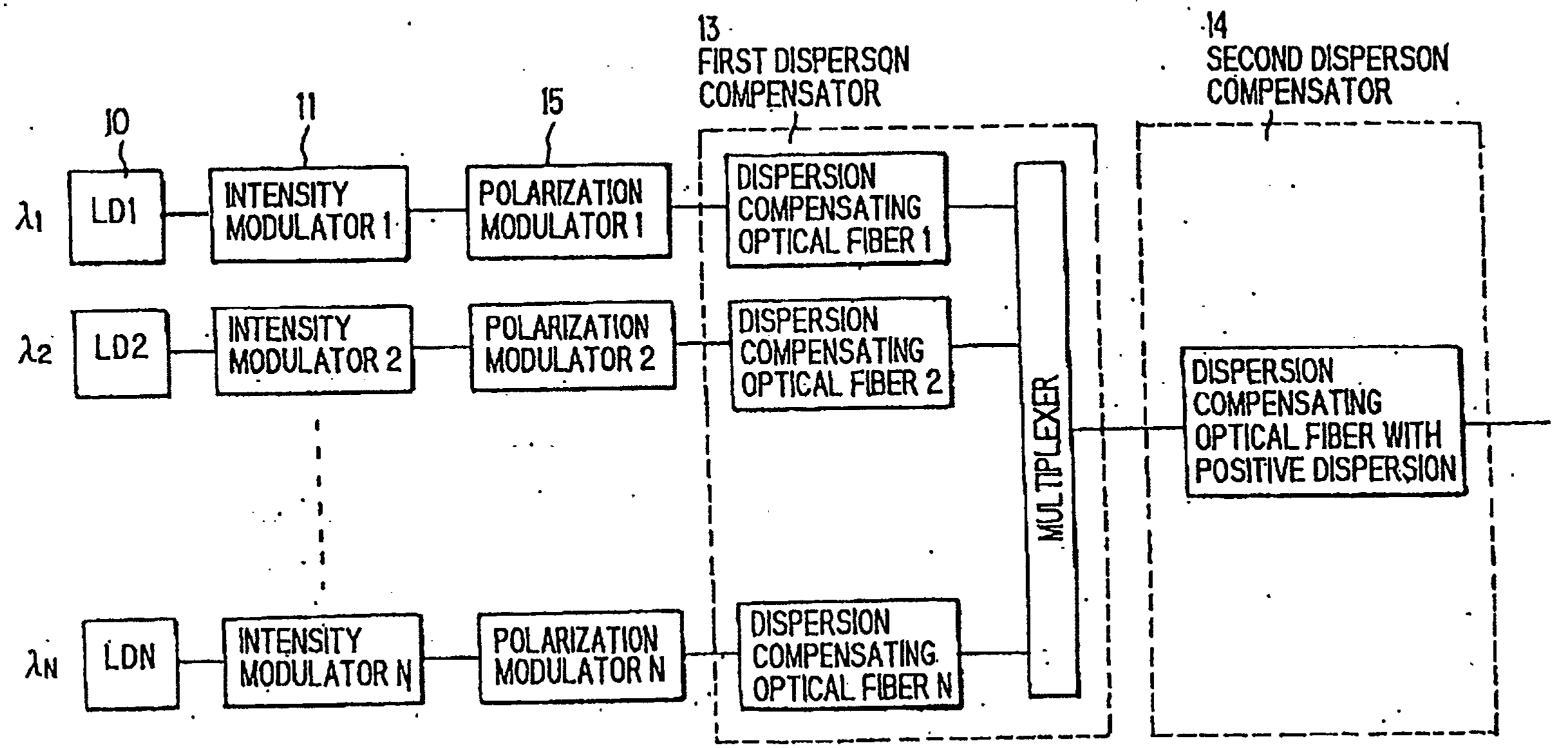
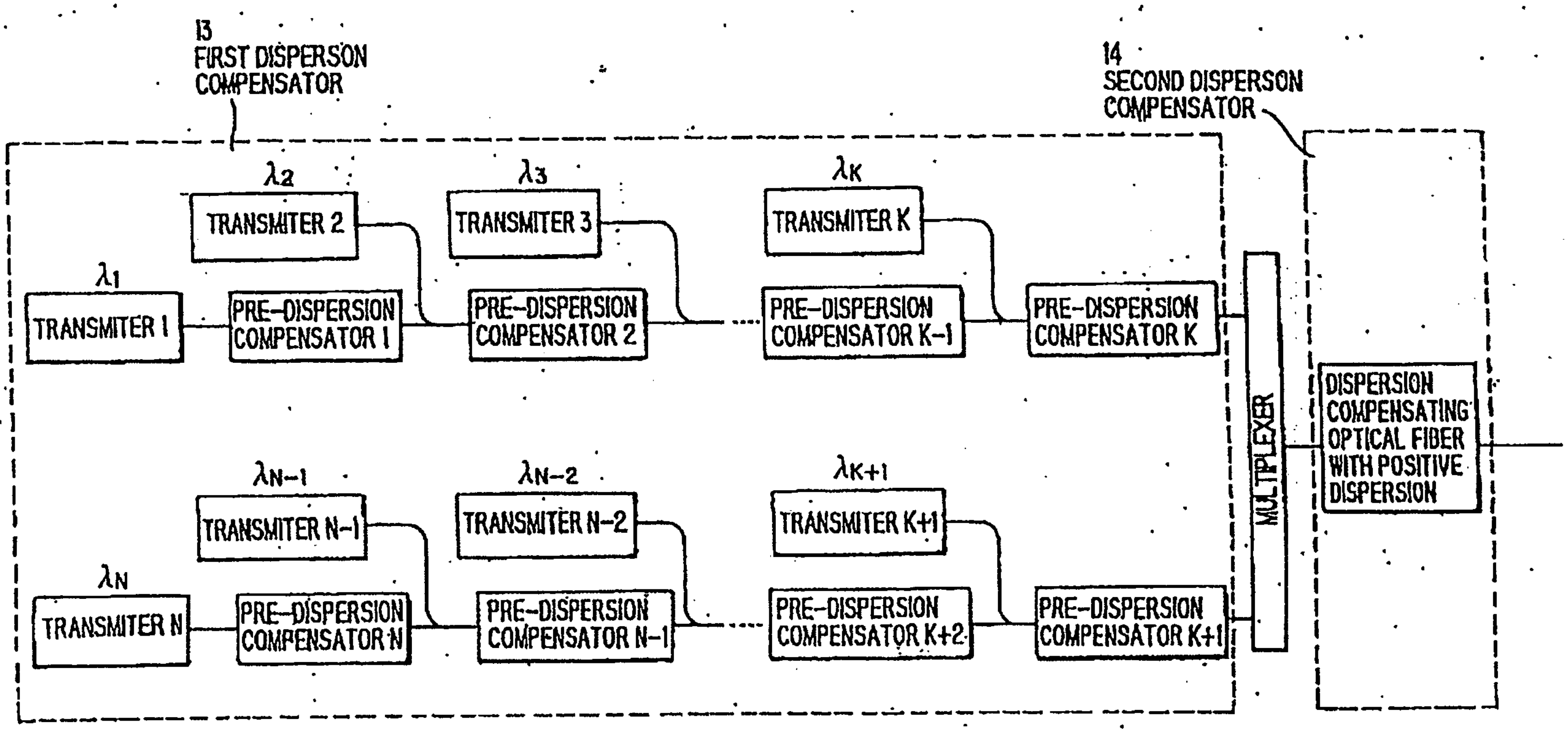

10
11
15
13
FIRST DISPERSON COMPENSATOR
14
SECOND DISPERSON COMPENSATOR
λ1
λ2
λN
LD1
LD2
LDN
INTENSITY MODULATOR 1
INTENSITY MODULATOR 2
INTENSITY MODULATOR N
POLARIZATION MODULATOR 1
POLARIZATION MODULATOR 2
POLARIZATION MODULATOR N
DISPERSION COMPENSATING OPTICAL FIBER 1
DISPERSION COMPENSATING OPTICAL FIBER 2
DISPERSION COMPENSATING OPTICAL FIBER N
MULTIPLEXER
DISPERSION COMPENSATING OPTICAL FIBER WITH POSITIVE DISPERSION

FIG.3


13
FIRST DISPERSON COMPENSATOR
14
SECOND DISPERSON COMPENSATOR
λ1
TRANSMITER 1
λ2
TRANSMITER 2
λ3
TRANSMITER 3
λK
TRANSMITER K
PRE-DISPERSION COMPENSATOR 1
PRE-DISPERSION COMPENSATOR 2
PRE-DISPERSION COMPENSATOR K-1
PRE-DISPERSION COMPENSATOR K
λN-1
TRANSMITER N-1
λN-2
TRANSMITER N-2
λK+1
TRANSMITER K+1
λN
TRANSMITER N
PRE-DISPERSION COMPENSATOR N
PRE-DISPERSION COMPENSATOR N-1
PRE-DISPERSION COMPENSATOR K+2
PRE-DISPERSION COMPENSATOR K+1
MULTIPLEXER
DISPERSION COMPENSATING OPTICAL FIBER WITH POSITIVE DISPERSION

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WDM OPTICAL SIGNAL TRANSMISSION APPARATUS

FIELD OF THE INVENITON

The invention relates to a long-haul (several thousand km or more) wavelength division multiplexed (WDM, hereinafter) optical signal transmission apparatus, and especially to a WDM optical signal transmission apparatus comprising an optical transmitter and an optical receiver with particular structures, and an optical transmission line with optimized dispersion distribution of optical fibers.

BACKGROUND OF THE INVENTION

Due to the development of optical fiber amplifiers with excellent characteristics, it has become possible that an optical signal is transmitted without electrical 3R-operations (re-timing, re-shaping and re-generation) in repeaters over a distance of several thousand km or more, and consequently the technology of the optical signal transmission is remarkably developed in reliability and economy.

As the result a transmission capacity more than 1 Tb/s in a single optical fiber is achieved.

The aforementioned improvements of the performance concerning a transmission distance and a channel capacity result from the fact that the optical amplifier repeater can amplify optical signals of one or more channels simultaneously. Studies for realizing a long-haul optical transmission of high capacity by using such optical fiber amplifiers and a

channel-multiplexing technology are now actively developed.

Recently, two experiments on long-haul optical signal transmission systems are reported, in which data for an optical fiber are that the number of channels is 32, a transmission speed per channel is 5Gb/s (a total capacity is 160 Gb/s) and transmission distance is about 10,000km ([1] Neals S. Bergano et al, OFC, '97, PD16, [2] N. Shimojoh et al, Electronics Letters, Vol.33, No.10, pp877-879, '97). In the experiment reported in the reference [1], the channels are allocated to both the normal and anomalous regions of the optical fiber, and dispersion accumulated in the optical transmission line is compensated at a receiving end in the lump.

In the experiment reported in the reference [2], the optical fiber with a similar characteristics is used, and dispersion accumulated in the optical transmission line is compensated at both the sending and receiving ends.

The important problems concerning the long-haul WDM optical communication are the improvements of the characteristics of the optical repeater amplifier (noise figure, gain bandwidth, flatness of gain and etc.), allocation of dispersion in the optical transmission line, compensation of the accumulated dispersion and suppression of various nonlinear effects generated in the optical transmission line.

As a problem caused by the nonlinear effect peculiar to the WDM optical communication, there is a wave form distortion due to the SPM-GVD effect, which occurs as the result of interaction between the self phase modulation and the group

velocity dispersion. The SPM-GVD effect is a wave form distortion cause by repetition of the spectrum spread due to the self phase modulation and the waveform distortion due to the chromatic distortion. Since it is a nonreversible process, it is difficult to recover the original wave form. This effect becomes noticeable as the wavelength of the optical signal is remote from the zero-dispersion wavelength.

It is desirable to decrease the amplitude of the optical signal propagating through the transmission line in order to suppress the SPM-GVD effect. However, the decrease of the amplitude of the optical signal brings about the decrease of optical SNR. Since the amplitude of the optical signal is determined dependently on the noise characteristic (the noise figure) of the repeater amplifiers, it is impossible to extremely decrease the amplitude of the optical signal.

As a method for increasing the endurance against the SMP-GVD effect other than the decrease of the light intensity of the optical, a method, in which a bit synchronous sinusoidal phase modulation is superimposed on an intensity modulated optical signal, is known ([3], Neal S. Bergano et al, OFC, '96, TuN1, 1996, for instance). However, phase modulation used in the aforementioned experiment is not pure phase modulation, but phase modulation through polarization modulation.

Two reasons can be considered for the facts that the transmission characteristic can be improved by superimposing the bit synchronous phase modulation on the optical signal. First, when an appropriate dispersion is added to a bit synchronous phase modulated optical signal, there arises an

effect that the waveform can be improved. Another reason is that, since the spectrum of the optical signal is excessively spread by the phase modulation, the waveform of the optical signal is steeply changed by the dispersion of the transmission line, and subsequently the peak power of the optical signal is decreased and thereby the self phase modulation is reduced.

On the improvement of the transmission characteristic achieved by superimposing the bit synchronous phase modulation on the optical signal, the optimum condition is described in the reference [3] based on the relation between intensity modulation component and a phase of a sinusoidal signal for phase modulation. On a method for compensating the dispersion accumulated in the transmission line at both the sending and receiving ends, the optimum construction is described in Japanese Patent Kokai 9-46318 [4].

In the experiment reported in the reference [2], although the noise characteristic of the optical repeater amplifier is below and the light intensity of the optical signal in the transmission line is set at a high level as compared with the experiment reported in the reference [1], the transmission performance achieved is superior to that achieved in the reference [1]. This result originates in the improved method for compensating the dispersion accumulated in the transmission line, which is disclosed in the reference [4].

In the improved method for compensating the accumulated dispersion disclosed in the reference [4], the half of the residual dispersion accumulated in the transmission line for each channel is compensated at both the sending and receiving

ends. On the other hand, in the experiment reported in the reference [1], the accumulated dispersion is compensated at the receiving end in the lump.

In the experiment reported in the reference [2], the optical signals of 32 channels are allocated from 1545.0nm to 1560.5nm with equal spacings of 0.5nm. Although the zero-dispersion wavelength of the transmission line is not written expressly, it is presumed to be about 1552.5nm from the spectrum spread of each channel caused by nonlinear effect of the transmission line. Since this wavelength is nearly equal to the enter wavelength of the channels, the channels of the same number are respectively allocated to the normal and anomalous dispersion regions as proposed in the reference [4].

It is described in the reference [4] that, since there is a difference in the transmission characteristic between the normal and anomalous. regions, the direction of the chirp to be superimposed on the optical signal should be respectively positive and negative in the normal and anomalous regions.

Near the zero-dispersion wavelength, although the transmission characteristics are excellent, the spectrum spread of the optical signal caused by the self phase modulation is noticeable. Accordingly, it is necessary to expand the spacing between the wavelengths of the adjacent channels in order to suppress a coherent crosstalk caused by overlap of the spectrums of the adjacent channels. Moreover, the light intensity of the optical signal should be reduced to some extent in order to suppress the spread of the spectrum of the optical signal, so that there is a limitation on the increase of the

optical SNR of the optical signal propagated through the transmission line.

The improvement of the resisting property of the optical signal against the SPM-GVD effect, which is achieved by the bit synchronous phase modulation, is not so noticeable in the anomalous dispersion region as compared with that in the normal dispersion region.

As mentioned in the above, there are following problems on a method, in which the channels are equally allocated to the normal and anomalous dispersion regions on both the sides of the zero-dispersion wavelength. One problem is that the operational conditions of the respective transmitters must be changed in accordance with the wavelengths of the channels. Another problem is that a particular attention must be paid to the spread of the spectrum of each optical signal near the zero-dispersion wavelength.

Accordingly, it can be concluded that it is advantageous to allocate all the channels to the normal dispersion region by keeping away from the anomalous dispersion region an the vicinity of the zero-dispersion wavelength.

However, in such a case, since a channel of shortest wavelength is remote from the zero-dispersion wavelength, a compensation of a large amount must be added to this channel, and the dispersion compensators at both the sending and receiving ends are magnified according to the technology disclosed in the reference [4].

SUMMARY OF THE INVENTION

Accordingly, it is an object of the invention to provide

a WDM optical signal transmission apparatus, which compensates a dispersion accumulated in an optical transmission line and suppresses various optical nonlinear effects of the same.

The present invention provides a wavelength division multiplexed (WDM) optical signal transmission apparatus, comprising:

an optical transmission line comprising optical fibers, in which all channels are allocated to a normal dispersion region of said optical transmission line, and

dispersion compensating optical fibers with positive dispersion respectively connected to said optical transmission line at transmitting and receiving ends thereof to compensate accumulated dispersion in said optical transmission line.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be explained in more detail in conjunction with appended drawings, wherein:

FIG. 1 shows a preferred embodiment of the invention,

FIGS. 2A and 2B show structures of dispersion compensators used in the preferred embodiment of the invention shown in FIG. 1, and

FIG. 3 shows another structure of the dispersion compensator used in the preferred embodiment of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Next, a WDM optical signal transmission apparatus according to the invention will be explained referring to the appended drawings.

FIG.1 shows a fundamental structure of the WDM optical signal transmission apparatus located on both the sending and receiving ends of an optical transmission line and a dispersion map of the optical transmission line.

As shown in FIG.1, the WDM optical signal transmission apparatus at the sending end is provided with transmitters 16-1 to N, which respectively correspond to channels with wavelengths of λ_1 to λ_N, the first pre-dispersion compensator 13, which is composed of dispersion compensators (optical fibers) 1 to N and a multiplexer for multiplexing the channels, and the second pre-dispersion compensator 14. The WDM optical signal transmission apparatus at the receiving and is provided with the second post-dispersion compensator 24, the first post-dispersion compensator 23, which is composed of a demultiplexer for demultiplexing the channels and the dispersion compensators (the optical fibers) 1 to N, and optical receivers 26-1 to N.

The optical transmission line 1 is so constructed that its average dispersion for each optical signal is a relatively small negative value and shows a slight negative inclination, when expressed as a function of a transmission distance. For example, the transmission line 1 is composed of optical fibers 2 with negative dispersion (NZDSFs(Non Zero Dispersion Shift fibers) with dispersion of about -2ps/nm/km, for instance) and the optical fibers 3 with dispersion of about +17ps/nm/km (the 1.3μm zero-dispersion optical fibers, for instance). In this way, dispersion of the transmission line 1 for each channel become a relatively small negative value.

A 1.3μm zero-dispersion optical fiber with dispersion

of +17ps/nm/km and a length of about 55km is connected with a NZDSF with a length of 500km. The transmission line 1 can be constructed by cascading the aforementioned combinations of the optical fibers. In such a transmission line, dispersions of the channels propagating therethrough are different from each other because of higher order dispersions. In order to make all the channels propagate in the normal dispersion region, the ratio the length of the NZDSF to that of the 1.3 μm zero-dispersion fibers is selected so that average dispersion of the transmission line is negative. Explaining more concretely, an average zero-dispersion wavelength of the transmission line 1 is set at a wavelength, which is longer than the longest signal wavelength by 1 to 2nm.

Since the transmission line is constructed so that all the channels are allocated to the normal dispersion region, the accumulated dispersion of each channel must be compensated at both the ends of the transmission line by adding positive dispersion. According to the technology disclosed in the reference [4], the dispersion compensator is enlarged, because dispersion accumulated in the transmission line is large.

In order to overcome the aforementioned disadvantage, the dispersion compensators located on both the sending and receiving ends are respectively separated into two parts in this embodiment. The structures of the dispersion compensators located on the sending and receiving ends are the same except directivities of optical amplifiers and etc..

Next, the dispersion compensators located on the sending end in this embodiment will be explained. The dispersion

compensator is composed the first dispersion compensator for the respective channels and the second dispersion compensator for the WDM optical signals.

The first dispersion compensators respectively compensate the differences in accumulated dispersions between the channels caused by higher order dispersions of the transmission line, and are respectively composed of dispersion compensating optical fibers with positive or negative dispersions in accordance with accumulated dispersions of the channels. Explaining concretely, a dispersion compensating fiber with a negative dispersion is used for a channel with a wavelength longer than that of a center channel, and a positive dispersion compasating fiber with a positive dispersion for a channel with a wavelength shorter than that of the center channel.

The second dispersion compensator is formed of a dispersion compensating fiber with a positive dispersion, which enable all the channels to propagate through the transmission line in the normal dispersion region. The second dispersion compensator compensates the half of dispersion of the center channel accumulated in the transmission line. A complete dispersion compensation can be achieved by the two second dispersion compensators located on both the ends of the transmission line.

As mentioned in the above, at the sending end, the respective channels pass through the first dispersion compensator, dispersion compensations of which are respectively determined by the wavelengths of the channels, a

transmission distance and higher order dispersions of the transmission line, are multiplexed by the multiplexer, and propagate through the second compensator formed of the optical fiber with positive dispersion.

On the other hand, at the receiving end, the received channel pass through the post-second dispersion compensator, are demultiplexed by a demultiplexer, and respectively pass though the first post-compensator for compensating the differences in accumulated dispersions between the channels. The post-second dispersion compensator is formed of the dispersion compensating optical fiber with a positive dispersion having the same structure as that in the sending end, and compensates the half of the dispersion of the center channel accumulated in the transmission line.

In this embodiment, the second dispersion compensator can be used as a part of the transmission line. Accordingly, the dispersion compensators to be located on the sending and receiving ends are the first dispersion compensators only, so that the dispersion compensators can be small-sized and simplified as compared with those in the technology disclosed in the reference [4].

Moreover, if a NZDSF with a dispersion of about +2ps/nm/km is adopted, the maximum residual dispersion of the channel corresponding to the shortest wavelength can be reduced, and consequently the transmission characteristic can be improved.

Next, the structure of the WDM optical signal transmission apparatus at the sending end and especially the structure of the dispersion compensator will be explained in

concrete terms.

FIG.2A shows the first structure of the dispersion compensator at the sending end.

At the sending end, the WDM optical signal transmission apparatus is provided with laser light sources (LD) 10 for generating optical signals with desired wavelengths, intensity modulators 11, which are connected with the laser light sources 10 and intensity modulate the optical signals by data signals; phase modulators 12, which are connected with the intensity modulators 11 and superimpose bit synchronous sinusoidal phase modulation on the intensity modulated optical signals, and the first pre-dispersion compensator 13, which is connected with the phase modulators 12. The first pre-dispersion compensator 13 is composed of dispersion compensating fibers with different dispersions for respective channels, and a multiplexer for multiplexing the channels. In case that a dispersion compensating fiber is long and an optical amplifier is necessary, the optical amplifier may be inserted in the dispersion compensating fiber.

The second dispersion compensator 14 is formed of an optical fiber with a positive dispersion, and connected with the output port of the multiplexer in the first dispersion compensator 13.

Dispersion to be added in the first and second dispersion compensators 13 and 14 can be derived as follows.

First, a dispersion to be added in the second dispersion compensator 14 will be determined in consideration of a

dispersion accumulated in the transmission line. The wavelength of the center channel is denoted by λ_c[nm], the zero dispersion wavelength of the transmission line is denoted by λ_0[nm], an average slope of a dispersion of the transmission line is denoted by a [ps/nm^{2}km], and the transmission distance is denoted by L[km].

In this case, the dispersion of the center channel accumulated in the transmission line is given by $a*(\lambda_c-\lambda_0)*L$. Accordingly, a dispersion to be added in the second dispersion conpensator 14 is $-a*(\lambda_c-\lambda_0)*L/2$.

Subsequently, a dispersion to be added to each channel in the first dispersion compensator 13 will be determined. An accumulated dispersion of a channel with a wavelength of λ in the transmission line is given by $a*(\lambda-\lambda_0)*L$[ps/nm]. The aforementioned dispersion is compensated by $-a*(\lambda_c-\lambda_0)*L$[ps/nm] in the second dispersion compensators located on both the sending and receiving ends. Accordingly, a total dispersion to be added in the first dispersion compensators allocated on both the sending and receiving ends is $-a*(\lambda-\lambda_c)*L$, hence a dispersion of $-a*(\lambda-\lambda_c)*L/2$ is assigned to both the first dispersion compensators.

FIG.2B shows the second structure of the WDM optical signal transmission apparatus at the sending end. This structure can be obtained by replacing the phase modulator 12 show in FIG.2A with a polarization modulator 15. It is well known that the transmission characteristic of a long-haul WDM optical transmission system is deteriorated by various effects depending on the polarization state of the optical signal, such

as polarization dependent losses of various components and polarization hole-burning in an optical amplification repeater. Accordingly, the polarization state of the optical signal is previously scrambled, and the optical signal is intentionally transmitted in the depolarized state. Since the bit synchronous polarization scramble, in which the optical signal is depolarized in a period of one bit, simultaneously superimposes a chirp on the optical signal, it has the similar effect to that of the bit synchronous phase modulation.

FIG.3 shows another structure of the first dispersion compensator. The transmitters of the respective channels have the plural pieces of pre-dispersion compensating fibers connected in series for common use. The dispersion of each piece of the dispersion compensating fiber is determined by the difference in the accumulated dispersions between the adjacent channels. According to this structure, since the channels use the dispersion compensation fiber jointly, the dispersion compensator can be small-sized.

According to the above, since the dispersion compensators used in the long-haul WDM optical signal transmission apparatus can be small-sized and low-priced, and all the channels can be allocated to the normal dispersion region of the transmission line with the excellent transmission characteristics.

Since each channel is not used in the zero-dispersion region and the anomalous dispersion region, the light intensity of the optical signal can be sufficiently increased as compared with the transmission system, which uses the aforementioned

wavelength regions.

Since the wavelength spacing between the adjacent channels largely affects the bandwidth and the gain-flatness of the optical amplification repeater and the dispersion compensation, it is desirable to make the wavelength spacing as narrow as possible. According to the above, since the consideration on the spectrum spread near the zero-dispersion wavelength is unnecessary, the wavelength spacing between the adjacent channels can be further decreased as compared with the conventional system in addition to the increase of the light intensity of the optical signal.

Moreover, according to the above, since all the channels are allocated to the normal dispersion region, there is no necessity for adjusting the operational conditions of the transmitters for the respective channels, and the transmitters of all the channels can operate in the same condition.

As mentioned above, the arrangement is suitable for constructing the transmission system suited for the long-haul WDM optical communication.

Although the invention has been described with respect to specific embodiment for complete and clear disclosure, the appended claims are not to be thus limited but are to be construed as embodying all modification and alternative constructions that may be occurred to one skilled in the art which fairly fall within the basic teaching here is set forth.

Each feature disclosed in this specification (which term includes the claims) and/or shown in the drawings may be incorporated in the invention independently of other disclosed and/or illustrated features.

Statements in this specification of the "objects of the invention" relate to preferred embodiments of the invention, but not necessarily to all embodiments of the invention falling within the claims.

The description of the invention with reference to the drawings is by way of example only.

The text of the abstract filed herewith is repeated here as part of the specification.

It is an object of the invention to provide a WDM optical signal transmission apparatus, which improves transmission characteristics by allocating all the channels to the normal dispersion region of an optical transmission line without magnifying dispersion compensators. The transmission line is composed of a main optical fiber, which covers the greater part of the optical transmission line, and two dispersion compensating optical fibers (the second dispersion compensators) located on both the ends of the main optical fiber. Since the transmission characteristic of the transmission line in the normal dispersion region is superior to that in the anomalous dispersion region, all the channels are allocated to the normal dispersion region of the main optical fiber. The dispersion compensators located on both sending and receiving ends are composed of the first dispersion compensators for compensating accumulated dispersions of the respective channels and the second dispersion compensators for compensating negative dispersion of the center channel accumulated in the main optical fiber. Since the second dispersion compensators can be used as the parts of the transmission line, the dispersion compensators located on both the sending and receiving ends can be small-size as compared with those in the conventional system.

CLAIMS

1. A wavelength division multiplexed (WDM) optical signal transmission apparatus, comprising:

an optical transmission line comprising optical fibers, in which all channels are allocated to a normal dispersion region of said optical transmission line, and

dispersion compensating optical fibers with positive dispersion respectively connected to said optical transmission line at transmitting and receiving ends thereof to compensate accumulated dispersion in said optical transmission line.

2. A WDM optical signal transmission apparatus according to Claim 1, wherein:

dispersion compensations in said dispersion compensating optical fibers are approximately equal.

3. A WDM optical signal transmission apparatus according to Claim 1 or 2, wherein:

said optical transmission line is constructed by alternately connecting optical fibers with positive dispersion and optical fibers with negative dispersion.

4. A WDM optical signal transmission system according to any preceding claim further comprising:

residual dispersion compensators for compensating the respective accumulated dispersion of channels in said optical transmission line, said dispersion compensating

optical fibers being located between residual compensators for a respective channel.

5. A WDM optical signal transmission apparatus according to Claim 4, wherein:

dispersion compensations for respective channels in said residual dispersion compensators are approximately equal.

6. A WDM optical signal transmission system according to Claim 4 or 5, wherein:

said residual dispersion compensator located on said transmitting end of said transmission line comprises a multiplexer and optical fibers, each of which compensates the residual dispersion of a corresponding channel and is inserted between an output port of a corresponding optical transmitter and a corresponding input port of said multiplexer.

7. A WDM optical signal transmission apparatus according to Claim 4 or 5, wherein:

said residual dispersion compensator located on said transmitting end of said optical transmission line comprises at least one series connection of a plurality of optical fibers for compensating residual dispersions of a plurality of neighbouring channels,

wherein a length of each of said optical fibers is determined by a difference in residual dispersion between adjacent channels.

8. A WDM optical signal transmission apparatus according to any of Claims 4 to 7, wherein:

said residual dispersion compensator located on said receiving end of said optical transmission line comprises a demultiplexer and optical fibers, each of which compensates the residual dispersion of a corresponding channel and is inserted between a corresponding output port of said demultiplexer and an input port of a corresponding optical receiver.

9. A WDM optical signal transmission system substantially as herein described with reference to Figure 1 of the accompanying drawings.

The Patent Office

INVESTOR IN PEOPLE

Application No:	GB 9820737.6	**Examiner:**	Stephen Brown
Claims searched:	1-9	**Date of search:**	28 January 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): H4B (BK18)

Int Cl (Ed.6): H04B: 10/18.

Other: Online : WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2 303 984 A	(Fujitsu) See especially page 14, lines 5-20, page 24, line 8, to page 25, line 6, figure 17, and claims 20 & 25.	1, 4, 6, 8
X	GB 2 299 473 A	(Hitachi) See especially the abstract, page 9, lines 9-12, page 11, lines 1-9, and figures 1 & 3.	1 & 3
X	GB 2 268 018 A	(Denwa) See especially page 12, line 25, to page 13, line 5, and figure 1.	1-3
X	EP 0 730 354 A2	(AT&T) See especially column 5, line 42, to column 6, line 20, and figures 1-4.	1-3
X	US 5 636 046	(Fujitsu) See especially column 33, lines 10-17, column 34, line 18. to column 36, line 9, column 37, line 65, to column 39, line 6, column 42, lines 23-34, and figures 28, 30, 34, & 36..	1, 4, 6-8
X	US 5 224 183	(Alcatel) See especially figures 2 & 3.	1, 4-6, 8

X Document indicating lack of novelty or inventive step
Y Document indicating lack of inventive step if combined with one or more other documents of same category.
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E Patent document published on or after, but with priority date earlier than, the filing date of this application.